BELLCOMM, INC.

SUBJECT: A Survey of Manned Mars and Venus Flyby Missions in the 1970's - Case 103-2

DATE: May 17, 1966

FROM: A. A. VanderVeen

ABSTRACT

The various classes of manned flyby trips to Venus and Mars are surveyed to present class descriptions and graphic comparisons of mass-in-Earth-orbit requirements, launch opportunities, and trip duration.

(NASA-CR-152882) A SURVEY OF MANNED MARS AND VENUS FLYBY MISSIONS IN THE 1970'S (Bellcomm, Inc.) 15 p

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MEMORANDUM FOR FILE

Introduction

Manned flyby trips to Mars and Venus are currently receiving widespread attention as probable missions in the sequence of events leading to manned exploration of those planets within the next two decades. This memorandum describes the various classes of flyby missions, and presents--mainly in graphic form--a comparison of the mass requirements, launch opportunities, and trip durations of representative missions of various classes of planetary flybys in the 1970's.

Mission Class Description

There are two basic classes of single-planet flyby missions, one of which has subclasses of practical significance. The non-symmetric class missions depart and arrive Earth at times when Earth occupies the same heliocentric position in space, a characteristic which yields integral-year trip durations, but which also places constraints on mission planning. They may also be thought of as limiting cases of the symmetric class of missions, which is considered here.

The symmetric class missions are of fractional year durations and are subclassed as high- and low-energy missions. High-energy missions are characterized by near coincidence of the trajectory aphelion and peri-planet passage point with a point on the Sun-planet line, either in front of (lightside passage) or behind the planet (darkside passage). Wide variations in mass requirements with mission year exist for lightside and darkside flybys of Mars, whose orbit is relatively eccentric, because Mars is encountered near aphelion of the transfer trajectory. Mars twilight missions, on the other hand, pass to the side of Mars and proceed well beyond the Martian orbit before returning to Earth. The trajectories can be adjusted to allow near-tangential Earth orbit departures and, hence, require less mass in initial Earth orbit than the high-energy type missions. These trajectories are essentially a perturbed two-year period orbit.

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Optimum twilight Mars flybys require trip durations of from 640 to 685 days, while lightside trips range from 580 to 650 days and darkside missions generally last from 495 to 545 days. However, there exists a unique set of darkside missions that require about one year duration. These are higher-energy type flybys, that cut inside of Venus' orbit on the outbound segment and encounter Mars on the inbound segment. The trajectory is essentially a one-year period orbit slightly perturbed by the Mars encounter, and both arrival and departure from Earth's orbit are highly non-tangential.

Since the orbits of Venus and Earth are nearly circular, there is little variation in Venus flyby requirements with mission year, and only one case is presented.

Wide variation in trip time is found in dual planet flybys to Venus and Mars in 1972 and 1978, during which years Mars is encountered near perihelion and aphelion, respectively; however, mass requirements are found to vary only slightly. Although only cases for 1972 and 1978 are presented, dual planet flyby missions during intermediate years are not precluded, but it should be kept in mind that there exists little data regarding such missions, and conclusions reached should be tempered accordingly. Sketches of representative mission profiles are found in Figs. 1 and 2.

Mission profiles and Vehicle Parameters

Free-return trajectories are the only trajectories considered, and it is assumed that they may be attained by means of a single-impulse propulsive maneuver from a 100-nmi Earth orbit performed by a single stage chemical system (λ = .91, I_{sp} = 450 sec). The trajectories are perturbed by close-approaches to the flyby planets (outside the planet's atmosphere) so that Earth is encountered at the proper time on Earth's orbit. Aerodynamic capture and braking from speeds of 50,000 ft/sec or less is assumed with retro-thrust capability to 50,000 ft/sec provided, if necessary, by means of a storable chemical propulsion system having a mass-fraction of 0.85 and I_{sp} = 300 seconds.

A recovery weight of 10,000 lbs is assumed, to which a heat-shield weighing between 4,000 and 5,071 lbs* (depending upon entry velocity) is added. The mission module weight was taken to be 90,000 lbs, and a 50 lb/day rate of expendable usage was set. No probe weights or excursion module weight was allowed.

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*Heat-shield weights are determined in accordance with TRW-STL Report #8423-6006-RV000.

The 1979 Mars twilight flyby mission was assumed for the nominal reference mission, and other missions are compared on a mass basis of 471,400 lbs = 1. The weight and performance values used in the mass calculations were assumed only for purposes of comparing mass requirements on a relative basis, and the calculated values of mass required in orbit should not be construed to represent accurate launch vehicle requirements.

Mass Calculations and Data Considerations

The trajectory data representing optimum launch opportunities for the various classes of missions and mission year was taken from Reference 1. The impulsive departure velocities given were adjusted to correspond to departures from a 100-nmi Earth parking orbit. The ideal velocities of arrival and departure as well as launch date, trip duration, and mass-in-Earth-orbit required are listed in Table 1. Table 2 has been included to provide a comparison between flyby and orbiter Mars missions in 1979 using identical vehicle parameters. Gravity losses at Earth departure were accounted for in the mass calculations by interpolation of curves prepared from integrated trajectory data. No ΔV allowance was made for midcourse corrections.

A comparison of mass requirements for the missions considered is presented graphically in Fig. 3.

Results

The mass comparisons shown in Fig. 3 support the discussion in Mission Class Description regarding relative energies and mass variations with mission year. It is noted that the twilight-passage Mars flyby missions are not strongly affected by mission year and are relatively economical, but their durations average 675 days.

The bonus feature of seeing two planets at the price of one is available, according to the limited data on dual-planet flybys, and the short trip duration corresponding to the 1972 mission makes this trip quite attractive, if manned Mars flyby mission development could be accelerated to meet this time scale. For that matter, if 1972-1973 missions are seriously considered, all classes of Mars flybys enter the competition, and guidance considerations and illumination patterns of Mars might well be the determining criteria of mission mode selection.

1021-AAV-nmm

A. A. VanderVeen

Attachments
Reference
Figures 1 - 3
Tables 1 and 2

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REFERENCE

"Manned Mars and/or Venus Flyby Vehicle Systems Study," North American Aviation, Inc., Report #SID 65-761-2, prepared under NASA contract NAS9-3499.

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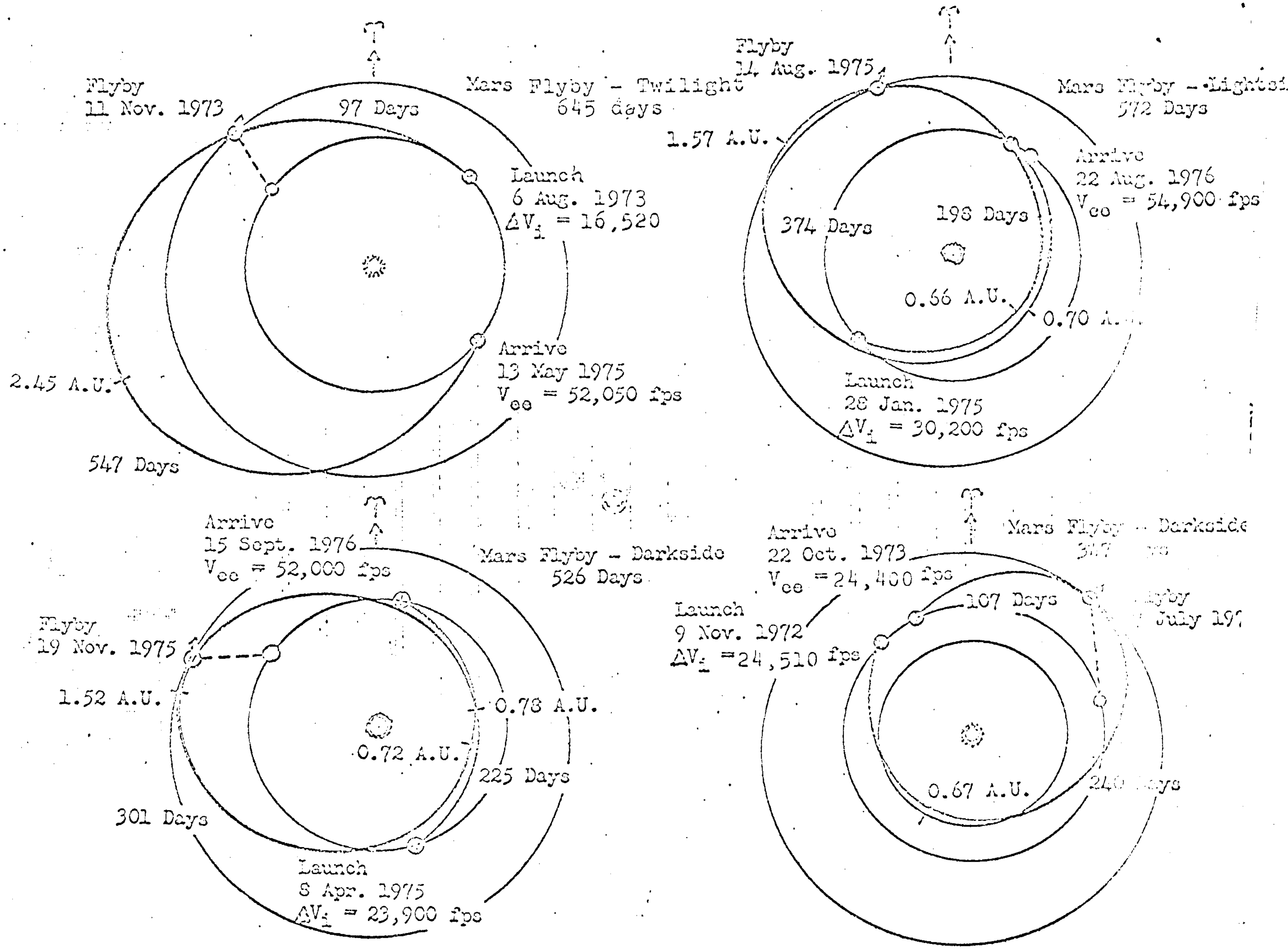
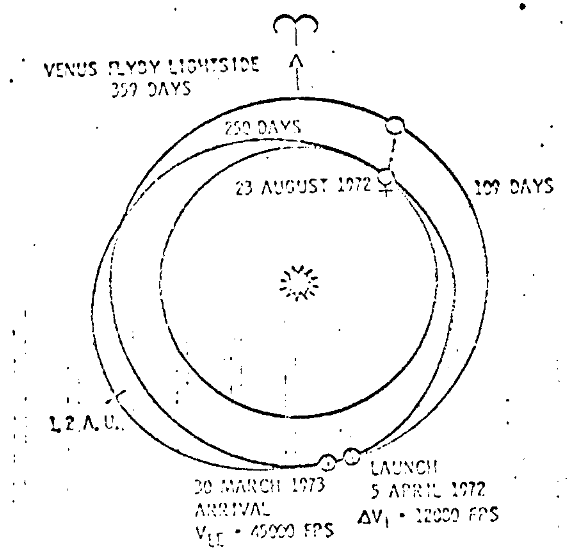


Fig. 1. Sketches of Mission Profiles



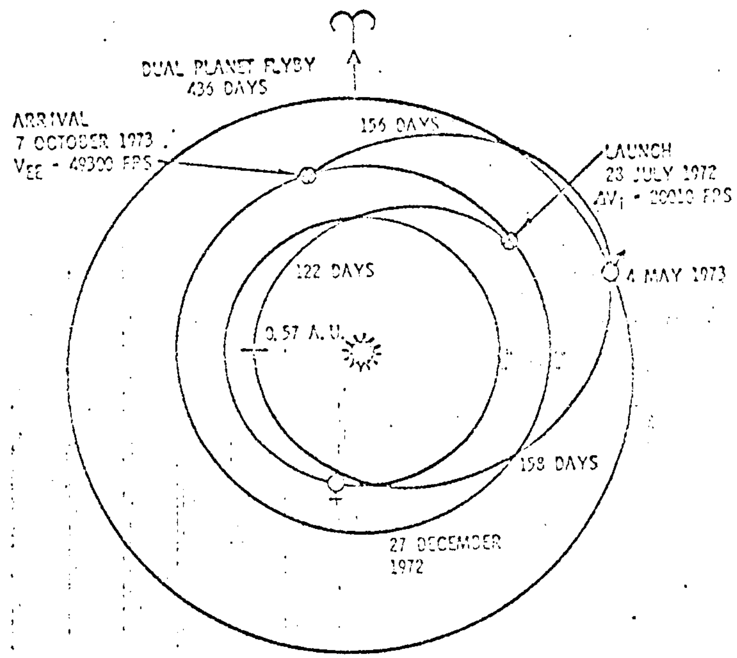


Fig. 2. Sketches of Mission Profiles

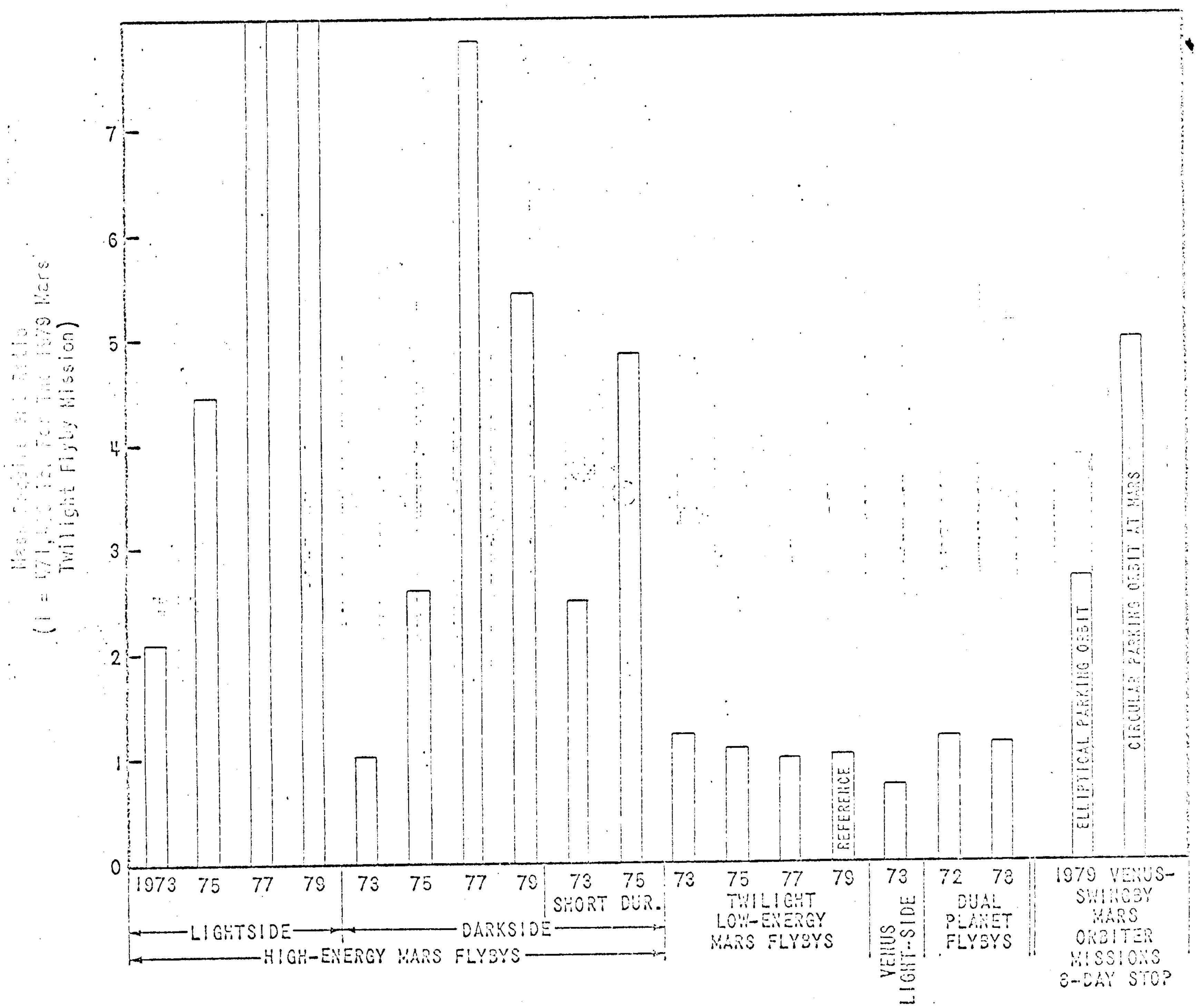


FIGURE 3 - MASS REQUIREMENTS FOR VARIOUS FLYBY AND ORBITER MISSIONS

TABLE 1. FLYBY MISSION CHARACTERISTICS

Launch Date: Calendar Date	Launch Date: Julian Date	Trip Duration: 1st leg/2nd leg (days)	Trip Duration: Total (days)	Velocities (ΔV's): Injection (ft/sec)	Velocities (ΔV's): Entry (ft/sec)	Mass Required in Earth Orbit 471,400 lbs = 1
Mars Flyby-Lightside Passage						
8 Jan 73	2441690	280/300	580	22,335	40,400	2.08
7 Feb 75	2442450	252/335	587	27,232	53,900	4.45
7 Apr 77	2443240	294/300	594	34,117	62,250	81.50
[illegible] Jun 79	2444050	345/250	595	39,715	62,680	*
Mars Flyby-Darkside Passage						
4 Mar 73	2441745	220/305	525	15,713	45,350	1.02
21 Apr 75	2442523	215/317	532	23,473	55,200	2.61
20 May 77	2443283	235/310	545	27,775	63,900	7.82
28 Jun 79	2444052	250/289	539	27,033	60,900	5.42
Mars Flyby-Short Duration, Darkside Passage						
9 Nov 72	2441630	240/107	347	24,509	51,500	2.51
8 Jan 75	2442420	245/110	355	28,316	52,700	4.84
Mars Flyby-Twilight Passage						
6 Aug 73	2441900	97/548	645	16,520	52,400	1.20
23 Sep 75	2442678	130/537	667	15,535	48,100	1.06
29 Nov 77	2443445	150/534	684	14,553	46,300	0.97
28 Nov 79	2444205	145/532	677	14,885	47,400	1.00
Venus Flyby-Lightside Passage						
14 Nov 73	2442000	104/252	356	12,346	44,500	0.70
Dual Planet Flyby-Earth-Venus-Mars-Earth						
11 Aug 72	2441540	135/257/72	464	17,405	49,000	1.18
26 Dec 78	2443868	142/230/253	625	16,125	45,000	1.10

*The thrust requirement is too great for the assumed vehicle.

TABLE 2. ORBITER MISSION CHARACTERISTICS

1979 Venus Swingby Mars Orbiter Mission

(8-day Stopover, 525 Days Duration)

	Date (Julian)	ΔV (ft/sec)	Mars-in-Orbit (lbs)
Depart Earth	2443840	14168	
Pass Venus	4000		
Arrive Mars	4162	11650 (7889*)	
Depart Mars	4170	11530 (7053*)	
Arrive Earth	4365	0	2,341,000 (1,268,000*)

*Elliptical Martian Parking Orbit

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